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WHITE-FRINGED BEETLES and How To Combat Them

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WHITE-FRINGED BEETLES AND HOW TO COMBAT THEM

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INTRODUCTION

White-fringed beetles cause severe damage to many field, truck, and garden crops in the Southeastern States. Most of the damage is done by the larvae feeding on the roots of plants. Both the larvae and adults can subsist on many kinds of plants. The beetles are capable of surviving under varied climatic conditions. Their occurrence from the Gulf coast to North Carolina makes their potential distribution in the United States a matter of concern. On the basis of the comparable climates in South America, where they are known to exist and whence infestations in the United States presumably came, white-fringed beetles may be expected to survive south of the latitude of New York City west to southern Iowa.

HISTORY AND DISTRIBUTION

In the spring of 1936 a farmer near Svea, Okaloosa County, Fla., reported to the county agent damage in a field of peanuts by numerous small grubs. During the summer of that year the county agent collected adults of the insect. These insects were identified as white-fringed beetles, not pre-

[1] In cooperation with the Alabama Department of Agriculture and Industries, the Florida State Plant Board, and the Mississippi State Plant Board.

viously known in the United States. The pest was reported the same year from the northern part of Walton County, Fla., and around Florala, Ala. In May 1937 destructive numbers were found in these localities attacking peanuts, velvetbeans, cotton, and corn. White-fringed beetles were also found in several localities in Louisiana and Mississippi in 1937. In July 1942 they were reported near Wilmington, N. C., and have since been found in several counties in that State. In 1946 and 1947 white-fringed beetles were found in a number of counties in Georgia and in two counties in South Carolina, and in 1948 and 1949 in two counties in Tennessee.

By the end of 1949 three species of white-fringed beetles—*Graphognathus peregrinus* (Buch.), *G. minor* (Buch.), and *G. leucoloma* (Boh.)—had been found at widely separated places in 135 counties in eight Southeastern States—Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee. *Graphognathus leucoloma* is represented by five races—*leucoloma dubius* (Buch.), *leucoloma fecundus* Buch., *leucoloma imitator* Buch., *leucoloma pilosis* (Buch.), and *leucoloma striatus* (Buch.).

The form originally found in the vicinity of Svea, Fla., and Florala, Ala., was *G. leucoloma fecundus*. In some of the infested localities only a few larvae or adults were discovered. It is not known whether all infestations have become permanently established.

The white-fringed beetles are natives of Argentina, Brazil, Chile, and Uruguay. The species given the name of *Naupactus leucoloma* Boh. was described in 1840 from material that had been collected in Tucuman, Argentina. The true *leucoloma* of Boheman is not known to exist in the United States. Only in recent years has crop damage by white-fringed beetles been reported from South America, where alfalfa, potatoes, lentils, beans, and peppers have been the crops most severely affected. Only in local areas are they considered major pests.

Graphognathus leucoloma was reported at Warrah Creek (near Willow Tree), New South Wales, Australia, where it was found attacking alfalfa late in the autumn of 1932 and in January 1933. Later investigations showed that it damaged vegetable crops, particularly beans, cauliflower, and cabbages.

MEANS OF SPREAD

So far as is known, all white-fringed beetles are females. No males have ever been discovered, and all adults are capable of laying fertile eggs. This peculiarity greatly increases the likelihood of dispersal and destructiveness, as any individual in any stage of development can start a new infestation. White-fringed beetles can be disseminated through commerce, in the egg, larval, pupal, or adult stage.

The eggs are deposited on many parts of plants and other objects that ordinarily move in commercial channels. The eggs hatch only under favorable conditions of moisture and temperature, and may remain viable for more than 7 months. Hay from infested fields often contains large numbers of unhatched viable eggs. The beetles may be spread in this way. Eggs, larvae, and pupae may be transported with soil attached to nursery stock, sod, and similar objects. The adults may be carried from place to place on seed cotton, hay, and other crops, as well as by vehicles, agricultural equipment, and man, because the beetles crawl readily and cling to such objects.

PLANTS ATTACKED

The larvae and adults have been observed to feed on 385 species of plants. Many of these plants, or their close relatives, are widely distributed in the United States. Plant hosts will therefore not be a limiting factor in the spread of these insects.

In the field white-fringed beetle adults have been found to feed on more than 170 species of plants, including field, garden, and truck crops, weeds, ornamental shrubs and flowers, wild bushes, vines, and trees. Some of the common host plants are alfalfa, beautyberry, beggarweed, blackberry, camphor, cocklebur, coffeeweed, cotton, dahlia, dewberry, gallberry, kudzu, lespedeza, lima bean, okra, peanut, ragweed, soybean, strawberry, teaweed, and velvetbean. In the laboratory, adults have fed on 215 species of plants, and have deposited fertile eggs when confined on any one of 184 species. Adults have also deposited fertile eggs when confined exclusively on moistened peanut hay, paper, and stems of dead plants. In the field, adults prefer plants with smooth leaves and stems to plants with hairy stems and foliage. They also prefer plants with large, broad leaves.

In the field, larvae have been observed feeding on 240 species of plants, some of the most common being alfalfa, beans, carelessweed, carrot, chrysanthemum, chufa, clover, cocklebur, corn, cotton, cowpea, curled-dock, Irish potato, lupine, mustard, oat, peanut, peas, ragweed, soybean, strawberry, sweetpotato, tobacco, and velvetbean. Larvae have also been found feeding on acorns, peach seeds, and pecan and tung nuts after the seeds had swollen and burst the hard covering. The larvae also feed on the roots of young woody plants, such as peach, pecan, tung, and willow, as well as on parts of dead plants in the soil.

DESCRIPTION OF STAGES AND LIFE HISTORY

The life history and habits of one species and of three races of another species of white-fringed beetles have been studied in the following areas: *G. peregrinus* at Gulfport, Miss.; *G. leucoloma fecundus* at Florala, Ala.; *G. leucoloma striatus* at New Orleans, La., and in Georgia; *G. leucoloma imitator* at Burgaw, N. C. Because the life histories and habits of all these forms are similar, only those of *G. leucoloma fecundus* will be discussed in this circular, and the differences between this and the other kinds will be merely mentioned.

The Adult

The adult of *G. leucoloma fecundus* (fig. 1) is approximately seven-sixteenths inch long and five-thirty-seconds inch across the abdomen. It is dark gray, with a lighter band along the outer margins of the wing covers, and two paler longitudinal lines on each side of the thorax and head, one above and one below the eye. The body is densely covered with short pale hairs, which are somewhat longer on the wing covers. The inner margins of the wing covers are fused together, and the underwings are rudimentary although they vary in size with the individual beetles. The adults cannot fly. Newly formed adults have a pair of mandibular cusps that cover their permanent mandibles (jaws) for use in cutting their way out of the soil. Soon after emergence the adults lose these cusps.

Figure 1.—Adult white-fringed beetles, shortly after emergence, resting on a stick while their body coverings harden. About natural size. (Photograph by W. N. Sharp, Soil Conservation Service.)

After emerging from the soil the adults usually crawl onto plants or other objects nearby and remain quiet for a few hours until their body coverings harden. Then they begin to search for food. If their favorite host plants and cover are near at hand they move about very little before they start egg laying; if such plants are scarce, however, the beetles will move about to find them. Adult beetles may crawl as much as one-fourth mile in their lifetime, but they remain on the plants or the soil surface.

The beetles are more active and egg laying is more pronounced in the afternoon than during the morning or night. Activity and egg laying are greatly reduced on cloudy and cool days.

The beetles begin to lay eggs from 5 to 25 days after they emerge. Those fed on the foliage of peanuts, soybeans, velvetbeans, and some weeds (cocklebur and ragweed) begin egg laying sooner than those fed on grasses. The preoviposition period is longer for *Graphognathus peregrinus* than for the other species.

The egg-laying period ranges from 30 to 60 days. Egg laying ceases or drops to a very low rate in the fall as soon as the temperature drops below 40° F. Most beetles die shortly after they have finished laying eggs.

Adults may live as long as 150 days after emergence, but most of them die within 90 days. Beetles fed on cotton, goldenrod, lambsquarters, ragweed, and smartweed live longer than those fed on legumes.

Eggs are deposited in masses of up to 60 or more, but the usual number per mass is from 11 to 14. The number of eggs deposited and the rapidity of oviposition vary greatly with the kind of plants fed upon. Beetles fed legumes and broad-leaved plants, such as cocklebur, giant ragweed, peanut, soybean, and strawberry, laid eggs rapidly and in large numbers. When fed their favorite food plants, the beetles deposited approximately 20 eggs a day. Adults feeding on the foliage of blackberry, cowpea, kudzu, lespedeza, Mexican clover, pecan, and tobacco laid fewer eggs; those feeding on grasses laid very few eggs and had a brief life span. At Florala, adults fed

peanut foliage deposited an average of 1,590 eggs; those fed on grasses deposited an average of 3.6 eggs.

Adults of *G. peregrinus* live longer than those of *G. leucoloma* but deposit eggs more slowly. Both *G. peregrinus* and *G. leucoloma imitator* deposit fewer eggs than *G. leucoloma fecundus* or *G. leucoloma striatus.*

The Egg

The egg (fig. 2) of the white-fringed beetle is oval and measures approximately 0.9 millimeter in length and 0.6 millimeter in width. When freshly laid it is milky white, but after 4 or 5 days the color changes to a dull light yellow.

The individual eggs and masses are covered with a sticky gelatinous substance which hardens after drying and causes the eggs to adhere to one another and to objects such as plant stems, roots, and soil (fig. 3). The egg masses are usually placed at the point of contact between the soil and the object on which the eggs are laid. Eggs are sometimes deposited directly into the soil to a depth of one-sixteenth to five-sixteenths inch; or they may be attached to the roots of plants. Occasionally, where plant growth was heavy, egg masses have been found on plants as much as several inches above the soil surface. Egg masses have been taken on cotton bolls, seed cotton, pecan nuts, velvetbean pods, corn husks, unshelled peanuts, cross ties, lumber, firewood, and farm implements where these objects were in contact with the soil.

Eggs deposited in June, July, and August hatch in 11 to 30 days, the average being about 17 days. Those laid in the fall and winter require

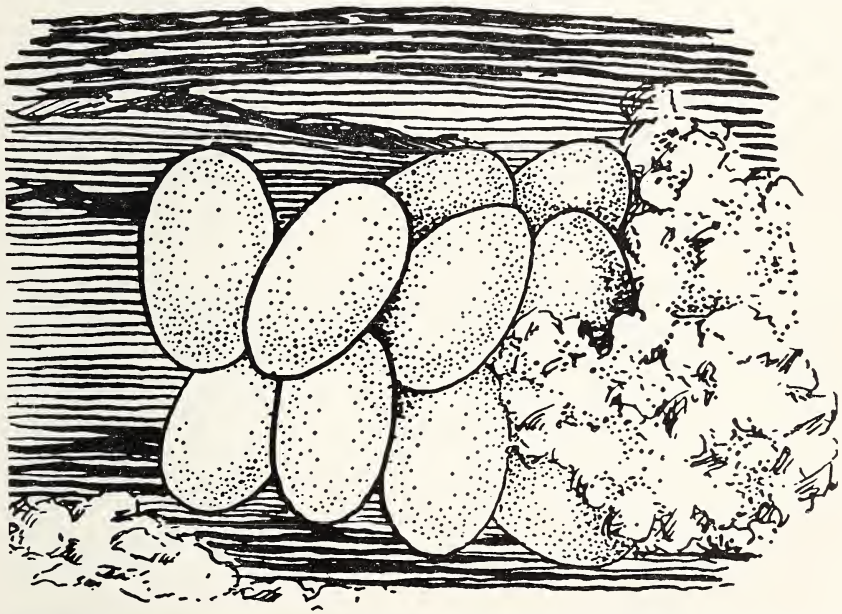

Figure 2.—White-fringed beetle egg cluster, with gelatinous covering and particles of soil partially removed to show arrangement of eggs. Greatly enlarged.

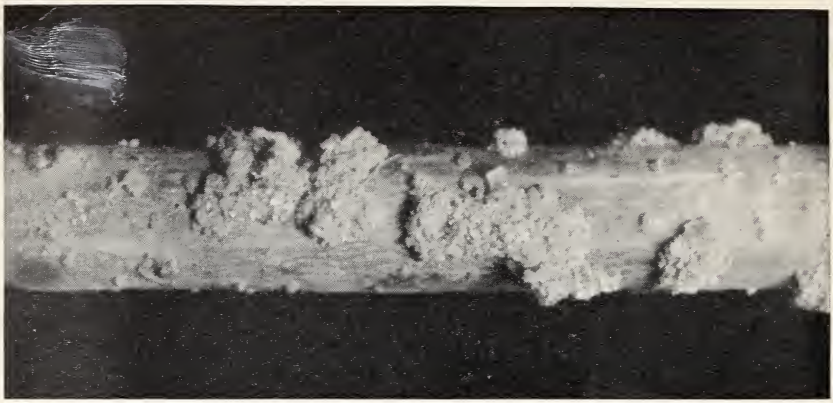

Figure 3.—White-fringed beetle egg clusters attached to stick and covered with gelatinous material and particles of soil. Slightly enlarged.

much longer periods for incubation, more than 100 days being required for those deposited in December. Over 90 percent of the eggs laid from June to November are viable, but at lower temperatures viability is greatly reduced.

When stored dry at natural temperatures in hay inside a barn, in haystacks outdoors, and among unshelled peanuts, some eggs deposited in late summer and early fall may remain viable throughout the winter and into the following spring. Although larvae complete their embryonic development within the eggs under dry conditions, they require moisture to emerge. Moisture also cools and softens the soil, making it favorable for the newly hatched larvae.

The Larva

The full-grown larva (fig. 4, *A*), which is legless, averages about one-half inch in length. It has a small, round, pale-brown head, and mouth parts fitted for gnawing. The body is yellowish white, fleshy, more or less curved, and sparsely covered with hair. It consists of 12 segments interrupted by 2 sublateral longitudinal grooves extending the length of the

Figure 4.—White-fringed beetle larvae (*A*) and pupae (*B*). About natural size.

body. The dorsal parts of the segments are bulging; the ventral parts are flattened. On each side, above the longitudinal grooves, small breathing pores are present on all segments except the second, third, and twelfth (last)

The entire larval stage is spent in the soil. After completing its growth the larva constructs a pupal cell (fig. 5). The inner surface of the cell is glazed with a secretion from the insect's body and is almost waterproof, but not entirely so, as the emergence of adults is inhibited by drought or by extremely wet conditions and stimulated by moderate amounts of moisture. Most of the larvae are found in the upper 9 inches of soil, but some have been taken to a depth of 24 inches, and a few at even greater depths.

Figure 5.—White-fringed beetle pupa in cell in soil.

The Pupa

The pupa (fig. 4, *B*) is approximately seven-sixteenths inch long. When first formed it is white, but within a few days the body and appendages gradually darken before transformation to the adult stage. Most larvae pupate from 2 to 6 inches below the soil surface. During the summer months the length of the pupal period is approximately 13 days; in cooler weather it is longer.

SEASONAL HISTORY

All species of white-fringed beetles discovered in this country have only one generation a year. They usually pass the winter in the larval stage, and some individuals have remained in the egg stage throughout the winter. During the winter months the larvae are less active. They come nearest the soil surface in March, April, and May.

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Most of the larvae that hatch during one summer emerge as adults the following summer, but a few remain in the larval stage for 2 years. Some of the larvae that hatch in the fall, winter, and early spring reach maturity and emerge as adults the first summer following hatching, but many do not reach maturity until the second summer. A few larvae of *G. peregrinus* require 3 years to reach maturity in the Gulf coastal area of Mississippi. Owing to the wide range in the dates of egg hatching and the difference in the rate of larval growth, larvae of various sizes can be found in the soil in any month of the year.

Under field conditions at Florala, Ala., pupation has occurred as early as April 26. Pupae are not numerous, however, until the first week in June, and pupation reaches a peak during the first 10 days of July. The time of pupation in the other infested areas is much the same as at Florala, except that *G. peregrinus* tends to pupate and emerge later than the other species.

The first adults usually emerge in May, and emergence extends into September or October, the greatest number of adults appearing in July. In the Florala area during the 4-year period 1938–41, 5 percent of the *G. leucoloma fecundus* adults had emerged by June 20 and 92 percent by July 30. Emergence in North Carolina occurs later than at Florala. *G. leucoloma striatus* emerges earlier than *G. leucoloma fecundus* at comparable latitudes.

The time of adult emergence varies considerably in different fields and also in different places within certain fields. This variation is caused by differences in date of egg deposition; moisture conditions during the periods of pupation, adult emergence, and after egg deposition; abundance of food for the larvae; and type and condition of soil.

Under field conditions the egg-laying period usually extends from June to late fall, the largest number of eggs being deposited from July 15 to September 15. Adults of *G. peregrinus* have deposited a few eggs throughout mild winters and as late as April in the Gulfport area.

Figure 6.—Irish potato plants, one of which (left) was killed by white-fringed beetle larvae. Long Beach, Miss.

NATURE OF INJURY

The principal damage is caused by larvae feeding on the roots and underground stems of young plants in the spring. Late in the summer or early in the fall larvae may also cause considerable damage by feeding on vegetable crops. They gnaw away the taproot and basal part of the stem but do little feeding on the small lateral roots. Sometimes they burrow into tubers, bulbs, and large seeds. Most of the feeding on roots extends from near the soil surface to a depth of about 5 inches. When feeding is severe the plants turn yellow, wilt, and die (fig. 6). Plants on which only a small portion of the cambium layer is eaten away usually survive but produce little or no crop.

The larvae are general feeders and they have caused injury to field and garden crops in a number of the infested areas. In some fields as high as 70 percent of the plants have been killed in areas ranging from a few square yards to 20 acres (figs. 7, 8, and 9).

White-fringed beetles do not usually damage crops uniformly over wide continuous areas as do some other insect pests. In large fields crop injury has ranged from a mere trace in one part to complete destruction in another. Frequently, after larvae have destroyed a stand and the field has been replanted, the larvae destroy much of the second planting. Where most of the stand has been lost and the crop abandoned, the result is a loss of fertilizer and seed, and of the cost of preparing and planting the land.

In the Florala area white-fringed beetles have damaged corn, cotton, and peanuts since 1936. The most extensive damage was in 1937, 1938, and 1942, when several hundred acres of field crops were a complete loss. In 1938 more than 1,000 acres of cropland were left unplanted because of the high population of larvae present. From 1943 through 1949, crop damage was very light and was confined to small areas within fields, although some fields have been infested since 1937. In many fields in recent years (1943–49) high populations (100 or more larvae per square yard) have not caused serious crop damage. Crop damage has not been severe on the same land

Figure 7.—Cotton field at Svea, Fla., damaged by white-fringed beetle larvae. July 1937.

for more than 2 or 3 consecutive years, because the larvae destroy so much of the vegetation that conditions are unfavorable for the adults. After 1 or 2 years heavy populations of larvae may again become established in areas that previously had severe crop damage.

Irish potatoes are susceptible to injury by larvae, and severe damage to this crop has been observed in many infested areas. Larvae feed upon the seed tubers and underground stems, and on the tubers—the part of the plant grown for market (fig. 10). In a seven-eighths-acre field at Gulfport, Miss., larvae in 1943 destroyed 36 percent of the seed potatoes in the soil before the sprouts appeared above ground. Only 6 percent of the plants

Figure 8.—Irish potato field at Long Beach, Miss., damaged by white-fringed beetle larvae. April 1943.

survived the attack. This field produced only 60 pounds of potatoes, and 83 percent of them were too severely damaged to be marketable.

Truck and garden crops can be seriously damaged by much lighter populations of white-fringed beetle larvae than can the general field crops. In the fall of 1943 an 8-acre planting of various truck crops at Wilmington, N. C., showed beetle damage to the stands ranging from 6 to 87 percent, with an average loss of 50 percent. Strawberry plants are also very susceptible to serious damage by larvae, and some garden plantings have been completely destroyed.

Tobacco plants are susceptible to damage by the larvae. Small plants are killed outright; larger plants are stunted and produce unmarketable leaves. Records of damage to tobacco in seven fields containing a total of 14 acres at Atkinson, N. C., in 1945, showed that from 3 to 32 percent of

Figure 9.—Corn field in Alabama, damaged by white-fringed beetle larvae. This field was planted twice to corn and fertilized.

Figure 10.—White-fringed beetle larvae in an Irish potato.

the plants were killed and from 1 to 20 percent severely stunted. The average loss of tobacco plants was 22 percent.

Small grains, which have a fibrous root system and can be seeded by broadcasting or drilling during the fall and winter, can withstand heavy infestations of larvae without appreciable damage. As white-fringed beetle larvae are not voracious feeders during the cooler part of the year, plants grown in the late fall and winter are not damaged to the same extent as those planted in spring. Pasture and lawn grasses can also withstand high populations of larvae.

The adults seldom injure plants seriously, but occasionally, when the beetles are numerous, they defoliate plants or badly injure the foliage. Adults prefer the foliage of broad-leaved plants, but they also feed on some small-leaved plants such as lespedeza.

NATURAL ENEMIES

Unfavorable weather and soil conditions, parasites, predators, and diseases are important factors in keeping white-fringed beetles in check.

In the United States nematodes are the only known parasites of white-fringed beetles. At least six species of nematodes have been found to be parasitic on the larvae, pupae, or adults. The widespread species are in the genus *Neoaplectana*, and are generally distributed throughout the Southeastern and Gulf Coast States. Nematodes are important enemies of white-fringed beetles only in the coastal flatlands of Harrison County, Miss., where a combination of ecological conditions is peculiarly favorable to them. These parasites, however, are abundant only in habitats that are favorable to their development and are almost always more prevalent in noncultivated areas than in cultivated fields.

In favorable habitats they kill many of the soil-inhabiting stages of the white-fringed beetle, but seldom are they sufficiently abundant to keep beetle populations low enough to prevent crop damage. In general, however, nematodes are of little importance because most of them remain below the soil level inhabited by the host insect and because their activities are reduced by insufficient soil moisture and adverse temperatures. Even in areas with environments favorable to the nematodes, soil conditions are so much more favorable to the host that the parasites are not able to effect substantial economic control.

A fungus—*Metarrhizium anisopliae* (Metsch.)—is known to attack the soil-inhabiting stages of the white-fringed beetles in the Gulf coastal area, but it kills few beetles.

Predators undoubtedly have considerable influence on white-fringed beetle populations. Toads feed voraciously on adult beetles. As many as 240 beetles have been taken from the stomach of a single toad. Lizards, turtles, snakes, mice, moles, and skunks, as well as birds, domestic fowls, and hogs, consume the beetles in the larval or adult stages. Carabid beetle larvae, horsefly larvae, wireworms, and adults and larvae of two species of tiger beetles have been observed killing white-fringed beetles in the field. In the laboratory adults of carabid beetles have fed freely on white-fringed beetle eggs. Other known predators are ants, pentatomid adults, and spiders.

CONTROL MEASURES

White-fringed beetles may be controlled by certain cultural practices and with insecticides applied to the soil.

Cultural Control

Summer legumes, such as peanuts, soybeans, velvetbeans, and crotalaria, provide good food and cover for the adult beetles and food for the larvae. They are favorable to heavy egg laying and high populations of larvae. The grasses, including corn and small grains, are poor foods for the adults, and beetles feeding on them lay few eggs. Plants with fibrous root systems do not suffer as heavy damage by larvae as those having taproots. Larvae do not feed heavily on crops growing in late fall and winter. These habits have made it possible to keep populations low by following certain cropping practices. These practices can be followed on farms in the Gulf and South Atlantic States where general farm crops are produced, but in areas where tobacco and truck crops are raised it may not always be possible to rotate crops in such a manner as to keep populations suppressed.

Cropping practices that will suppress white-fringed beetle populations are outlined briefly:

1. Plant oats, or other small grains, for grain and grazing, on the heavily infested portion of the farm.
2. Do not plant more than one-fourth of the cropland each year to such summer legumes as peanuts, soybeans, velvetbeans, or other plants that are favorable foods for adult beetles. Do not plant them on the same land oftener than once in 3 or 4 years.
3. Do not intercrop corn with peanuts, soybeans, crotalaria, or velvetbeans, and prevent broad-leaved weeds such as cocklebur from growing among the corn. Fertilize corn heavily with a commercial fertilizer and turn under a winter-grown manure crop.

Even though peanuts, soybeans, and velvetbeans are preferred hosts of the adults, they need not be eliminated from the cropping system. When these crops are grown on the land only once in 3 or 4 years and then followed by a succession of such crops as oats, corn, and cotton, the population of larvae in the soil does not increase to the extent that they do appreciable damage.

Addition of organic matter to the soil reduces the number of plants killed by white-fringed beetle larvae. An economical method of adding organic matter to the soil is by growing and turning under winter cover crops. Thorough disking of the soil at 10-day intervals in June and July will kill a large proportion of the pupae.

Control With Insecticides

White-fringed beetle adults feeding on ornamental shrubs and flowers may be controlled with cryolite or DDT applied as a dust or a spray. The cryolite should contain at least 85 percent of sodium fluoaluminate.

For use as a dust, apply the cryolite at full strength and the DDT dust at a concentration of 3 to 5 percent DDT. Apply the dusts at the rate of 12 to 15 pounds per acre when the plants are moist and the air is calm.

To prepare a cryolite spray, add 10 to 12 pounds of cryolite to 100 gallons of water; for small quantities, 1½ ounces of cryolite to 1 gallon of water. For a DDT spray, add 2 pounds of a 50-percent DDT wettable powder or

4 pounds of a 25-percent DDT powder to 100 gallons of water; for small quantities, add one-third ounce of a 50-percent powder or two-thirds ounce of a 25-percent powder to 1 gallon of water. Apply the sprays when the plants are dry, as soon as the adults begin to feed on the plants. Spray the foliage until the liquid begins to drip from it.

Apply the cryolite and DDT dusts and the cryolite spray at 7- to 10-day intervals, and the DDT spray at 10- to 15-day intervals throughout the periods when adults are attacking plants.

Do not apply cryolite or DDT to foliage for the control of white-fringed beetles on field, garden, or truck crops because the large number of applications required lead to excessive cost and prohibitive residues.

Caution.—DDT and cryolite are poisons. Avoid contamination of food and livestock feed. Thoroughly clean all vessels and tools used in mixing DDT before using them for other purposes. Wash the hands and clothing thoroughly after handling DDT or cryolite.

Do not apply DDT on any plants the foliage of which is to be eaten by man or animals. Avoid using DDT on plants growing near fish ponds or streams, as there is danger of killing fish and other aquatic life.

IN FIELDS

Field infestations of white-fringed beetle larvae can be controlled by treating the soil with DDT. One application of 10 pounds of DDT per acre gives good control of the larvae for several years. Apply the dust or spray evenly over the surface and thoroughly mix it into the upper 3 or 4 inches of soil; a disk harrow can be used. A tractor disk gives excellent results, especially if the land is disked twice. The DDT can also be applied to the soil surface if it is turned under with a tiller and disked once. The insecticide can be more readily and thoroughly mixed with soil that crumbles easily than with soil that is excessively wet or dry.

Even distribution of DDT over the soil surface may be accomplished in several ways.

One method is to apply 20 pounds of 50-percent DDT or 40 pounds of 25-percent DDT per acre with a dusting machine. Point the nozzles of the machine downward, and make the applications when the air is calm to prevent drifting and blowing of the insecticide.

Another method is to mix 20 pounds of 50-percent DDT with approximately 500 pounds of thoroughly pulverized dry sandy soil or sand—enough for treating 1 acre. These materials can be mixed on a floor with shovels, in the same way that fertilizer is mixed on the farm. Shovel the DDT-soil or DDT-sand mixture from pile to pile until the insecticide is thoroughly dispersed in the soil or sand. If necessary add a little water to the mixture to reduce drift from wind. Spread the mixture over the land by hand or by means of a rotary or spreader-type fertilizer distributor. Whether you apply it with a dusting machine or a fertilizer distributor, or by hand, divide the material to treat a given area into two equal lots—one lot to be applied to the land in one direction and the other lot at right angles to the first. This procedure will give a more uniform distribution of the DDT.

Small larvae are more readily killed by DDT than are large larvae. White-fringed beetle larvae are most active during the warmer part of the year. Broadcast the soil treatments when the land is prepared for a crop,

in the fall, winter, spring, or summer. Best results are obtained when the DDT is applied in advance of spring planting.

ON GARDEN PLOTS

On small plots of land, such as flower beds and vegetable gardens, mix the DDT with dry sandy soil or sand and apply it on the surface. Then thoroughly mix it into the upper 3 or 4 inches of soil with a hoe or potato fork. Work the soil backward and forward several times to distribute the DDT thoroughly. One ounce of 50-percent DDT is sufficient for 140 square feet.

ON ROW CROPS

For protection of row crops, such as corn, cotton, soybeans, and peanuts, apply DDT in the drill row in the spring immediately before or at time of planting. Mix the DDT with soil or sand as previously described and apply it by hand or with a fertilizer distributor at approximately the same depth as the seed is to be planted. This method is less effective against subsequent populations than the 10-pound broadcast treatment, but it will prevent larval damage during the spring. Applications of DDT in the drill row at the rate of 2½ to 5 pounds per acre annually for 3 or 4 years, or until 10 to 15 pounds have been applied per acre, have given excellent crop protection, as well as enough residual DDT to keep down populations for several more years without additional applications.

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